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Revegetation studies on disturbed overburden: Emery coal field: 1980 annual progress report

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1980 ANNUAL PROGRESS REPORT

REVEGETATION STUDIES ON DISTURBED OVERBURDEN

EMERY COAL FIELD

by

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FOREST SERVICE STUDIES AT THE EMERY COAL FIELD

The problem of aridity at the Emery coal field with respect to revegetation was discussed in the Introduction to the 1979 Annual Progress Report. Most of that information will not be repeated here. In most years, precipitation amounts are insufficient in April, May, and June to sustain a satisfactory stand of seedlings or to permit the successful planting of shrub nursery stock without some supplemental watering. Spring and early summer precipitation deficiency may be compensated for in years when the overwinter precipitation is significantly greater than the long-term mean for that period.

Precipitation during the 1979-1980 winter was exceptionally high at the Emery research site. Nearly as much precipitation fell in Castle Valley during the months of November 1979 through April 1980 (6.47 inches at Ferron) as usually occurs for an entire year. Also, the 1980 growing season (May through October) was "normal" with respect to total precipitation, primarily because of several good storms in early May and early September. Thus, grasses made exceptionally good growth in 1980. Growth of shrubs was less spectacular. Precipitation throughout the autumn of 1980 and early winter was below normal.

Previous reports have contained results from six revegetation studies at the Emery site exclusive of the study on microclimate. This report updates information from these studies and includes other information on supplements to these studies. In some cases, 1980 data is compared with data from prior years to show changes with time.

FOREST SERVICE STUDIES AT THE EMERY COAL FIELD, UTAH

Several studies on revegetation have been established on different soil series at the Emery site beginning in the fall of 1977. In this report, these studies are discussed separately according to study number.

Study No. 1 (Response of Selected Grasses to Soil Amendments on Topsoil and Subsoil of the Persayo Series)

Objectives: (1) To determine effects of organic soil amendments on growth and development of selected grasses, (2) to compare response of selected grasses on both topsoil and subsoil of the Persayo series.

Methods:

Persayo soils constitute one of the main soil series in the Emery Coal Field. These soils are calcareous, well drained, and moderately fine textured. They occur on hills having gently sloping to steep topography and having formed in place by weathering from shale. Shale bedrock often occurs at a depth of 12 to 15 inches, but most subsoil material is a silty clay loam.

On the Emery site selected for this study, simulated mining involved removal of topsoil to a depth of 15 inches, ripping the subsoil to a depth of 30 inches with a D-9 caterpillar tractor, smoothing the furrows (left after ripping) with a dozer blade, and replacement of topsoil. Topsoil was replaced on one half of this particular area to permit comparison of plant growth on topsoil and on subsoil. For this study, topsoil was not replaced on an area 90 x 100 feet in size for comparison with an area of similar size having topsoil replaced.

Amendment treatments on both topsoil and subsoil included: (1) alfalfa hay spread at the rate of 2-1/2 tons per acre and rotovated 8 inches deep into the soil, (2) Kaibab compost spread at a depth of 1 inch and rotovated approximately 6 inches deep into the soil, and (3) no amendment (control). The amendment plots were 15 feet wide and 100 feet long, replicated twice on both replaced topsoil and subsoil.

Seeds of the first seven species shown below were broadcast in subplots 10 x 15 feet in size on each of the 15- x 100-foot main plots on December 6, 1977. Seeds of the last 3 species were unavailable on that date but were planted on March 21, 1978. Thus the study was set up in a randomized block, split-plot design having two replications (blocks). Species and amounts of seed used per plot were as follows:

		Grams/Plot
1.	"Nordan" crested wheatgrass (Agropyron desertorum)	16
2.	Induced fairway tetraploid X crested wheatgrass (A. desertorum).	16
3.	"Fairway" crested wheatgrass (A. cristatum)	32
4.	Russian wildrye (Elymus junceus)	32
5.	Indian ricegrass (Oryzopsis hymenoides)	32
6.	Squirreltail grass (Sitanion hystrix)	32
7.	Alkali sacaton (Sporobolus airoides)	16
8.	Blue grama (Bouteloua gracilis)	16
9.	Sand dropseed (Sporobolus cryptandrus)	16
10.	Palmer penstemon (Penstemon palmeri)	16

Results

Higher-than-average precipitation during the first 3 months of 1978 produced good germination and emergence of the first six species in the spring of 1978. Alkali sacaton showed little or no germination from the fall planting, and the last three species listed showed little or no germination from spring planting. Because of poor response from seed of the warm-season grasses, container-grown plants of the last four species were planted on these plots in May 1980, except that Hilaria jamesii replaced Penstemon palmeri. Grass transplants showed excellent survival in 1980.

Data taken July 12, 1978, showed that frequency and numbers of seedlings were greatest on the alfalfa hay mulch plots, followed by the control (no mulch) plots, and Kaibab compost plots, in that order. There was little difference in frequency and numbers of seedlings between the topsoil and subsoil areas, but plants were taller on topsoil plots. The three wheatgrasses and Russian wildrye had the best overall ratings among species.

In 1979, percent frequency of grass plants on topsoil (84%) was not significantly different from their frequency on subsoil (81%). Comparable figures for 1980 were 75% frequency on topsoil and 71% on subsoil. Estimated herbage yields in 1979 were 1079 pounds per acre (green weight) on topsoil compared to 610 pounds per acre (green weight) on subsoil. Difference in overall production in 1980 was less pronounced being 510 pounds per acre (dry weight) on topsoil and 476 pounds per acre (dry weight) on subsoil.

In 1980 as in 1979 plant frequency for both alfalfa hay and no mulch (check) treatments were superior to the compost (Table 1).

Table 1. Mean frequency (percent) of grass seedlings for three soil amendments on Persayo soils*

Alfalfa hay	Check	Compost
86	75	58

*Means underscored by the same line are not significantly different (P<.05)

One of the most striking differences in the third growing season (1980) was superior production of grasses where the alfalfa hay amendment had been applied prior to planting in the fall of 1977. Grasses on this treatment were darker green in color than elsewhere suggesting increased uptake of nitrogen by plants. Analysis of herbage for nitrogen content in the laboratory confirmed that fact. Plants growing on the alfalfa hay treatment contained from 1/3 to 3 times higher nitrogen content than plants on the other treatments.

Table 2. Mean air dry yields (lbs/acre) for three soil amendments on Persayo soils*

Hay	Compost	Control
646	435	399

*Means underscored by the same line are not significantly different (P<.05)

As in 1979, mean yields in 1980 for the six cool-season grasses show that the three introduced wheatgrasses were more productive than the other three species (table 3.)

Table 3. Mean yields (lbs/acre air dry) of six cool-season grasses on Persayo soils*

Agcr(H)	Agde	Agcr	Elju	Sihy	Orhy
724	666	549	447	380	193

*Means underscored by the same line are not significantly different (P<.05)

Relatively high production in 1980 will likely not be equaled again. Past experience has shown that reseeded grasses usually reach a peak production in the third or fourth growing seasons and then plateau at a somewhat lower level of production. That fact plus exceptionally high soil moisture content during the growing season, combine to give the high yields shown in table 3.

The high productivity in 1980 is reflected also in height growth as shown in table 4. Overall mean heights in 1980 were approximately one-fourth greater than in 1979.

Table 4. Mean flower stalk height (inches) of six cool-season grasses[1] on Persayo soils in 1979 and 1980*

	Agcr(H)	Orhy	Agde	Sihy	Agcr
1979	12.2	12.0	11.3	9.6	8.3
1980	15.8	15.3	14.8	11.8	10.1

[1]There were no standing flower stalks of Elju in 1979 or 1980. A few appeared to have been cutoff by small mammals in 1980.

*Means underscored by the same line are not signficantly different ($P<.05$)

It should be remembered that the three wheatgrasses used in this study plus Russian wildrye are introduced species from Eurasia, whereas Indian ricegrass and squirreltail grasses are native to this country. The superiority of the introduced species in the crested wheatgrass complex for revegetating arid ranges has been demonstrated over a long period of time in this country. These are now often referred to as naturalized grasses, similar in effect to smooth bromegrass and Kentucky bluegrass which are also introduced but proven adapted in many situations.

Study No. 2 Response of Grasses to Soil Amendments on Topsoil and Subsoil of the Penoyer Series

Objectives: (1) To compare growth and development of selected grasses on both topsoil and subsoil of the Penoyer series, (2) to determine response of grasses to organic amendments on topsoil and subsoil.

Methods:

This study is similar in design to Study No. 1, except that it was established on Penoyer soils approximately 1 mile from the 6-acre Persayo soil site.

Penoyer soils are well drained, calcareous, and medium textured. They have formed in alluvium from sandstone, limestone, and basic igneous rocks. The surface layer is typically a light brownish-gray, strongly calcareous loam about 9 inches thick. The underlying material is light brownish-gray loam and very fine sandy loam to a depth of over 60 inches.

As in Study No. 1, simulated mining involved removing topsoil to a depth of 15 inches, ripping the subsoil to a depth of 30 inches with a D-9 caterpillar tractor, smoothing the furrows (left after ripping) with a dozer blade, and replacement of topsoil. Topsoil was not replaced on an area 90 x 100 feet in size for comparing subsoil with topsoil as growing media for plants.

As in Study No. 1, the study was established in a randomized-block, split-plot design. One kind of main plot treatment involved the two soil types (subsoil and topsoil) and a second kind of main plot treatment, 15 x 100 feet in size involved three amendments (hay, compost, control), replicated twice on each soil type. Ten small species subplots, 10 x 15 feet in size occurred on each 15- x 100-foot amendment main plot. Species and rates of seeding were the same as those shown in Table No. 1. Plantings were to be made in the fall of 1977, but snow storms caused planting to be delayed on this site until March 29, 1978.

Results

Fair germination occurred following spring planting, but seedlings were only about one-half as numerous as seedlings from fall planting (Study No. 1) when data were taken on July 12, 1978. Again seedlings were most numerous on the alfalfa hay mulch plot and fewest on the Kaibab mulch plot. Plant frequency data tended to follow that of plant numbers with respect to treatments. Of course, seedlings from spring planting were smaller than the seedlings from fall planting, and the smaller seedlings will be more vulnerable to summer drought.

In the second growing season (1979) plant frequency of grasses was equal on topsoil and subsoil of the Penoyer series (81 and 82 percent, respectively). Again, herbage yields were considerably higher where topsoil had been replaced over subsoil. Estimated yields of 323 pounds per acre (green weight) on subsoil was only 57 percent of the estimated yields of 562 pounds per acre on topsoil. Data for 1980 follow.

As on Persayo soils, plant frequency on Penoyer soils was highest on the alfalfa hay and no mulch treatments and lowest where compost was used (Table 5).

Table 5. Mean frequency (percent) grasses for three mulch treatments on Penoyer soils*

Alfalfa hay	Check	Compost
74	70	49

*Means underscored by the same line are not significantly different (P<.05)

As on Persayo soils, the three wheatgrasses produced more herbage in 1980 on Penoyer soils than the other three cool-season grasses (Table 6). The induced hybrid crested wheatgrass and Agropyron desertorum (both tetraploids) produced more herbage than fairway crested wheatgrass (diploid). Air dry forage yields in 1980 were higher than green weight yields in 1979. Yields on Penoyer soils were also higher than yields on Persayo soils.

Table 6. Mean yields (lbs/acre air dry weight) of six cool-season grasses on Penoyer soils*

Agde	Agcr(H)	Agcr	Elju	Orhy	Sihy
1078	1051	882	601	550	252

*Means underscored by the same line are not significantly different (P<.05)

As would be expected, culm heights in 1980 (Table 7) were also much higher than in 1979. Russian wildrye produced flower stalks on the sandy loam Penoyer soils, whereas it didn't produce stalks on Persayo soils. It is unlikely that the 1980 heights will be exceeded in the future.

Table 7. Mean culm heights (inches) for six cool-season grasses*

Elju	Agde	Agcr(H)	Orhy	Agcr	Sihy
21.8	20.6	20.3	16.0	14.9	9.3

*Means underscored by the same line are not significantly different (P<.05)

Study No. 3 Revegetation Techniques on Persayo Soils Following Simulated Mining at the Emery Coal Field

Objectives: (1) To evaluate effects of surface cultural treatments on plant survival and growth on Persayo soils on a 6-acre study site at Emery, (2) To compare the success of selected species of grasses and shrubs when seeded together in a mixture.

Methods

This study was established on Persayo soils that had been severely disturbed by what has been termed "simulated mining." It differs from Study No. 1, also on Persayo soils, in having larger cultural treatment plots and involving a seed mixture of selected grasses and shrubs. Simulated mining involved removal of topsoil to a depth of 15 inches, ripping the subsoil to a depth of 30 inches with a D-9 caterpillar tractor, and replacement of topsoil. Following simulated mining, the main surface cultural treatments involved: (1) a gouger-seeder which leaves a pitted soil surface, (2) a springtooth-type harrow to cover seed following broadcasting of the seed with a cyclone hand seeder, and (3) a cultipacker to firm loose soil following broadcasting seed with a cyclone hand seeder. In addition, two types of organic mulches were rotovated into the soil ahead of the main cultural treatments for comparison with no mulch.

A limited amount of grass hay was found to be available, and it was added in one strip for comparison with alfalfa hay mulch.

The seed mixture shown below was used in the gouger-seeder and also broadcast on all other treatments at the rate of 20 pounds per acre, December 14-15, 1977. During the seeding process, the flow of seed in the gouger-seeder stopped each time the pitting discs were raised out of the ground by the hydraulically-operated ram. The equipment operator from Missoula, Montana, was unable to correct the situation in the field, so we proceeded to use the implement in that condition. In effect, seed was placed only in the pits and not on ridges between pits.

Common name	Scientific name	Pounds
Crested wheatgrass	Agropyron cristatum	3
Streambank wheatgrass	A. riparium	3
Russian wildrye	Elymus junceus	3
Indian ricegrass	Oryzopsis hymenoides	2
Alkali sacaton	Sporobolus airoides	1
Fourwing saltbush	Atriplex canescens	2
Nevada ephedra	Ephedra nevadensis	2
Whitesage	Ceratoides lanata	2
Shadscale	Atriplex confertifolia	2
		20

Results

All treatments showed generally good seedling emergence in the spring of 1978. Gouged areas showed lower frequency of plants than the cultivated and cultipacked treatments. Alfalfa and grass hay mulch were generally superior to the Kaibab compost and no mulch treatments. Again competition from annual weeds (Kochia scoparia) in the alfalfa mulch might have affected seedling survival and growth during the hot, dry summer of 1978.

Overall plant frequency declined about 15 percent for grasses and 6 percent for shrubs in 1979 from what they had been in 1978. Little decline occurred in 1980. Greatest decline in both grasses and shrubs occurred on the gouged treatment. This is believed due to loss of plants on ridges between pits. Despite some loss of plants, sufficient numbers remain for successful stands under all treatments. Overall yields in 1980 were significantly higher where alfalfa hay mulch was used in the fall of 1977.

Data for the third growing season for four grass species and two shrubs are presented in Tables 8, 9, and 10. Crested wheatgrass (Agcr) was superior to other grasses. Shadscale (Atco) was superior to white sage (Cela).

Table 8. Mean frequency (percent for 4 grasses and 2 shrubs in mixture planting*

Agcr	Elju	Atco	Agri	Cela	Orhy
48	28	20	17	10	10

*Figures underscored by same line are not significantly different (P<.05)

Table 9. Mean yield (lbs/acre air dry) for 4 grasses and 2 shrubs in mixture planting*

Agcr	Atco	Elju	Agri	Cela	Orhy
552.7	309.3	148.4	86.7	62.6	35.0

*Means underscored by same line are not signiticantly different (P<.05)

Table 10. Mean height (inches) for 4 grasses and 2 shrubs in mixture planting*

Agcr	Agri	Orhy	Elju	Cela	Atco
15.8	13.8	12.8	8.5	7.2	6.8

*Means underscored by same line are not significantly different (P<.05)

Study No. 4 Revegetation Techniques on Penoyer Soils Following Simulated Mining

Objectives: The objectives of this study are essentially the same as in Study No. 3 except this study is on Penoyer soil series (1) To evaluate effects of surface cultural treatments on seeding success of a grass-shrub mixture, (2) Compare the success of species of grasses and shrubs when seeded together in a mixture.

Methods

This study involved some of the same treatments used in Study No. 3, but it was established on Penoyer soils; combinations of three mechanical surface treatments with three mulch treatments. Mechanical surface treatments included use of a gouger, cultipacker, and springtooth harrow. The three mulch treatments included (1) alfalfa hay rotovated into the replaced topsoil at the rate of 2-1/2 tons per acre, (2) Kaibab compost spread 1 inch deep and rotovated into the topsoil, and (3) no mulch (control).

Simulated mining prior to applying the above treatments involved removal of topsoil to a depth of 15 inches, ripping the subsoil to a depth of 30 inches with a D-9 caterpillar tractor, and replacement of topsoil.

Seed was hand broadcast prior to the cultipacker and harrow treatments whereas the gouger-seeder seeded and gouged in one operation. All seeding was at the rate of 20 pounds per acre in early December, 1977, using the same mixture that was used in Study No. 3.

Results

Data taken on July 28, 1978 showed that frequency of grass seedlings was highest on the alfalfa hay mulch areas followed by the control and Kaibab compost treatments. Frequency differences due to mulch were less pronounced for shrubs than for grasses. For both grasses and shrubs, the harrowed treatment showed higher frequency of plants than the gouged and cultipacked treatments.

Overall herbage yields in 1979 were highest on the harrowed treatment and least on the gouged area treatment. Again, fewer plant numbers on ridges between pits on the gouged area is believed responsible for lower overall yields on this treatment. As explained earlier, the gouger did not distribute seed properly between pits. Otherwise, plant vigor was excellent in pits and the full story on surface treatments is not yet known. It is expected that plants will survive better in the pits where moisture accumulates through drought periods.

Data taken in 1980 shown on Tables 11, 12, and 13 shows that the Penoyer soils were more productive than the Persayo soils discussed in Study No. 3. Again, crested wheatgrass was the most productive of four grasses. Frequency and yields of each of the four grasses were generally superior to the three shrubs. This area should be monitored for at least 2 more years to determine changes with time.

Table 11. Mean frequency (percent) for 4 grasses and 3 shrubs in mixture planting.

Agcr	Elju	Agri	Orhy	Cela	Atco	Atca
51.4	18.2	14.9	9.2	7.1	3.4	1.4

*Means underscored by the same line are not significantly different (P<.05)

Table 12. Mean yield (lbs/acre air dry) for 4 grasses and 3 shrubs in mixture planting

Agcr	Elju	Agri	Orhy	Atco	Cela	Atca
1264.0	149.2	122.6	85.7	73.5	53.9	22.7

*Means underscored by the same line are not significantly different (P<.05)

Table 13. Mean height (inches) for 4 grassea and 3 shrubs in mixture planting*

Agcr	Agri	Orhy	Atca	Elju	Cela	Atco
21.1	16.4	16.2	11.4	11.3	9.2	7.4

*Means underscored by the same line are not significantly different (P<.05)

Study No. 5: Revegetation Techniques on Disturbed Castle Valley Soils at the Emery Coal Field

Objectives: (1) To determine the revegetation potential of severely disturbed Castle Valley soils, (2) To compare subsoil of this soil series with topsoil as a growing medium for plants.

The Castle Valley Soil Series is found on upland benches and mesas over sizable areas in the relatively large Emery coal field. This soil consists of a shallow sandy loam over sandstone bedrock that tends to fracture and weather quite readily when exposed on the surface. Areas of these soils are generally surrounded by scarp faces of very steep, shaly, colluvial land or rock land. Depth of soil over bedrock varies from less than 10 inches thick to over 20 inches thick in areas where deposition by wind has occurred.

Methods

This study was established in the fall of 1977 on a 2-acre hilltop site above the 4-acre site where Penoyer soils are being tested. Approximately 12 inches of topsoil were removed from the north one-third of the area and stockpiled for use in Study No. 6. The undisturbed part of this area and the area having topsoil removed were ripped to about a 32-inch depth using a D-9 cat. The same seed mixture of grasses and shrubs used in Studies 3 and 4 was broadcast on both ripped areas at a rate of 20 pounds per acre.

Results

Fair germination and emergence of seedlings occurred on all treatments in the spring of 1978. Subsequent survival and growth was best on the ripped topsoil area. Seedlings on the area where topsoil had been removed remained small in 1978, whereas, some crested wheatgrass plants on the ripped area headed out the first growing season.

Both 1979 and 1980 productivity on the ripped area where topsoil had not been removed was comparable to productivity on Persayo and Penoyer soils (Studies 3 and 4). Most grass plants occur in the furrows made by the ripper teeth where competition was removed by the ripping operation. The most important finding to date in this study is the distinct advantage of topsoil over subsoil from the standpoint of plant growth and development. Grasses on the subsoil area remained small and had the appearance of seedlings throughout the second growing season (1979). Plants on subsoil remained relatively small throughout the 1980 season.

Study No. 6 Adaptability of Selected Container-Grown Shrubs on Different Soils of the Emery Coal Field

Objectives: (1) To compare survival and growth of a variety of selected container-grown shrubs on different soils in the arid climate of the Emery coal field, (2) To evaluate effects of two levels of supplementary water on plant survival and growth.

Methods

The study involved transplanting selected container-grown shrubs (2 to 6 inches high) in small plots 6 x 12 feet in size on each of four sites: Persayo, Penoyer, and Castle Valley soil series plus a blue-colored shaly subsoil typical of much of the area. Each site accommodated 20 species plots replicated four times. Species were planted in a randomized-block design with four replications (blocks) on each site. Each plot contained two rows of four plants each. Rows, and plants within rows, were spaced 36 inches apart.

Selected shrubs were grown from seed in the greenhouse during the winter of 1977-78. Field planting dates on the four sites were as follows, in the spring of 1978:

Penoyer soils	April 12 and 13
Blue shale subsoil	April 13 and 14
Persayo topsoil	April 19 and 20
Castle Valley topsoil	April 20 and 21

A few species that were not available on these dates were added later. One liter of water was applied to each plant at the time the container-grown plants were transferred to the field. Thereafter, all plants were given 1 liter of water on June 5 and July 20. Plants on the blue shale site were each given 1 liter of water on June 29, when they appeared to be under stress, but other plants did not receive water at that time. In late summer, plants of only two replications on each site were each given 2 liters of water on August 24 and again on September 12.

Results

Container-grown shrub species survived well and made excellent growth during the 1978 growing season on all soils, except the blue shale subsoil. Extra water added to one half of all plots was most beneficial to plant survival on the blue shale site; some mortality occurred on this site where plants did not receive extra water. Little mortality occurred on any of the other three sites with or without extra water. Average height of plants at the end of 1978 growing season was greatest on the Castle Valley topsoil; plants on this site averaged about 3 inches taller than on any other site.

The advantage of supplemental water in 1978 had disappeared by the spring of 1979 due to above-average precipitation in the winter of 1978-1979. Shrub growth continued to be least on the blue shale subsoil. Although certain shrub species averaged greater height growth on specific soil types, no significant differences occurred among the three types of topsoils.

Blue shale subsoil was the least favorable to shrub survival and growth of the four soils studied, through the second growing season. Otherwise, overall shrub survival was high on the three topsoils, with the Castle Valley topsoil exhibiting the best overall survival percentage (96.6). Prostrate summer cypress showed overall highest survival, but survival of several other species was nearly as high.

No data were taken in the spring of 1980. However, visual observations indicated that many plants had suffered partial dieback or death as the result of the dry growing season of 1979. Data taken in September 1980 supported this observation (Table 14), although some plants that appeared dead might recover. All shrub plots will be carefully checked in the early summer of 1981 to ascertain the survival at that time.

In the spring of 1979 container-grown plants were used to replace shrubs that had died during the first year. The data in Table 14 only shows survival of the original (1978) plantings. In future reports we will present data on the survival and growth of the replacement plants.

Table 15 shows the mean height of shrub species on the four soil types at the end of the third growing season (1980). Height was obtained by measuring a plant from among those growing on each 6 x 12 foot plot which appeared to represent the average size of survivors. The overall mean for that species was calculated from the four replications. The relatively poor condition of many plants at the end of the 1980 growing season made exact height measurements difficult, but most heights were slightly less than in 1979 (Table 9, 1979 Annual Report). As in 1979, overall shrub height was greater on the lighter-textured Penoyer and Castle Valley topsoils.

Table 14 . Mean percent survival of shrubs on four soil types at end of third growing season (1980), and percent change since autumn of 1979

Species symbol	Soil types: Blue shale	Persayo	Penoyer	Castle Valley	Mean
Arno	50.0(-9)[1]	65.0(-20)	81.2	75.6(-21)	68.0(-12)
Atap	37.5(-3)	59.4(-16)	56.2(-22)	100.0	63.3(-10)
Atbo	81.2(-6)	84.4(-6)	81.2(+3)	93.8(-6)	85.2(-4)
Atca	93.8(+13)	25.0(-75)	75.0(-25)	71.9(-25)	66.4(-28)
Atca x Atcu	95.8	56.2(-41)	87.5(-13)	96.9(-3)	84.1(-14)
Atca x Attr	62.5(+2)	np[2]	50.0(-42)	100.0	70.8(-13)
Atca x Atid	59.4(-24)	np	78.1(-13)	np	68.8(-18)
Atga	71.9(-8)	65.6(-34)	81.2(-6)	100.0	79.7(-14)
Atid	np	81.2(-13)	np	93.8(-3)	87.5(-8)
Atob	75.0	84.4(-16)	90.6	100.0	87.5(-4)
Atro	25.0(-13)	56.2(-44)	37.5(-44)	96.9(-3)	53.9(-26)
Atto	50.0(+12)	18.8(-50)	50.0(-12)	71.9(-23)	47.7(-18)
Attr	78.1	40.0(-60)	93.8(-3)	68.8(-19)	70.2(-21)
Atna	0	6.2(-75)	0(-25)	75.0(-12)	20.3(-44)
Camo	81.2(-6)	84.4(-13)	84.4(-6)	78.1(+3)	82.0(-5)
Cela	68.8	96.9	81.2(-9)	96.9	86.0(-2)
Cepa	100.0(+4)	np	90.6(-6)	100.0	96.9(-1)
Epne	50.0(-9)	100.0	100.0	100.0	87.5(-2)
Erco	62.5	18.8(-53)	56.2(-31)	np	45.8(-28)
Grsp	43.8(-19)	100.0	87.5(-13)	95.8	81.8(-8)
Kopr 4	96.9(-3)	96.9(-3)	87.5(-3)	100.0	95.3(-1)
Kopr 7	100.0	np	100.0	np	100.0
Kopr 9	87.5	np	100.0	np	93.8
Kopr 11	np	100.0	np	96.9(-3)	98.4(-2)
Kopr 12	np	100.0	np	100.0	100.0
MEAN	70.0(-3)	67.0(-26)	75.0(-12)	91.1(-5)	

[1]Numbers in parentheses show change in percent survival since September, 1979. No number indicates no change.

[2]np = species not planted on this site.

Table 15 . Mean height (inches) of shrub species on four Emery coal field soil types after three growing seasons

Species symbol	Blue shale subsoil	Persayo topsoil	Penoyer topsoil	Castle Valley topsoil	Means
Arno	4.8	10.9	14.2	10.1	10.0
Atap	6.2	14.7	10.3	14.0	11.3
Atbo	8.4	13.7	14.0	15.7	13.0
Atca	8.5	17.5	17.2	21.0	16.0
Atca x Atcu	11.7	16.5	20.6	17.7	16.6
Atca x Atid	5.2	np	13.0	np	9.1
Atca x Attr	2.8	np	11.2	13.8	9.3
Atid	np	9.9	np	13.8	11.8
Atga	4.7	10.5	8.8	13.2	9.3
Atna	0.0	12.0	0.0	13.9	6.5
Atob	4.3	9.1	9.5	14.0	9.2
Atro	3.5	10.3	9.3	12.9	9.0
Atto	2.0	11.0	6.2	10.6	7.4
Attr	4.3	8.2	12.6	15.4	10.1
Camo	11.5	10.4	10.7	8.5	10.3
Cela	5.9	14.2	15.5	14.6	12.6
Cepa	4.4	np	18.8	14.0	12.4
Epne	3.9	7.5	8.5	8.5	7.1
Erco	9.0	9.0	10.7	np	9.6
Grsp	5.1	12.5	10.8	12.6	10.2
Kovi	20.1	19.5	27.0	19.5	21.5
Kopr 7,11	15.5	16.0	24.0	13.0	17.1
Kopr 9,12	15.6	19.5	25.8	18.8	19.9
MEANS	7.5	12.6	14.2	14.1	11.7

Supplement No. 1
to Study No. 6: Compatability of Scarlet Globemallow and Alkali Sacaton with Different Shrubs

Objectives: (1) To compare growth and development of a forb and grass with the various shrub species used in this study.

Methods

Container-grown plants of Sphaeralcea coccinea and Sporobolus airoides were planted between established shrubs on each of the four major soil types used in this study as follows:

(1) 8 plants of Sphaeralcea were spaced between the 8 shrub plants on each plot in one of the 4 blocks (reps) on each site.

(2) 8 plants of Sporobolus were spaced between the 8 shrub plants on each plot in one of the 4 blocks (reps) on each site.

(3) 4 Sphaeralcea plants and 4 Sporobolus plants were planted alternately between the 8 shrub plants on each plot in one of the 4 blocks on each site.

(4) One of the 4 blocks on each site was left as is without adding Sphaeralcea or Sporobolus. A diagram showing the 1979 treatments applied to the 4 blocks on each site is attached (in the Appendix).

In addition Sporobolus airoides was planted on the blue shale subsoil, as described above. Sphaeralcea was not planted on the blue shale subsoil because of a lack of planting stock.

Approximately 1 liter of water was added to each plant at the time of transplanting, in early April 1979. Due to the very dry summer in 1979, a similar amount of water was added to each plant on the following dates throughout the growing season:

May 15-16
June 12-13
July 2-3
July 24-25
August 7-8
August 27-28
September 10-11
October 3-4

Results

The main effort in 1979 was to keep plants alive during the first growing season by adding supplementary water as needed. Survival appeared to be relatively high on all sites when watering was discontinued in October. Survival and development will be monitored at the beginning and end of the growing season over the next few years.

Observations in September, 1980, showed that survival of alkali sacaton was excellent on the blue shale subsoil, and nearly as high on Penoyer and Castle Valley topsoils (Table 16). Persayo topsoil and Blue Gate shale gave the lowest survival of alkali sacaton. The complete survival on the very clayey, blue shale subsoil may be explained by its high moisture-holding capacity and a minimum of competition with shrubs. Most shrubs, that were planted in the spring of 1978, have grown poorly on the blue shale subsoil, and their roots have probably not spread as far as on the other soils.

Data on the survival of scarlet globemallow was recorded according to ecotype (seed source) on three of the study sites. While the data have not been tested by statistical methods, it appears that ecotypes from Gunnison, Utah and the Desert Experimental Range in Millard County, Utah have fared better than the ecotypes from Ouray and Alton, Utah.

Many globemallow plants, on all sites, looked quite vigorous in the early summer of 1980, and many plants flowered and set seed. In contrast, very few alkali sacaton plants on any site have set seed after two growing seasons.

Table 16.--Second season percent survival of Sporobolus airoides and Sphaeralcea coccinea on different soil types when interplanted with established shrubs. Emery coal field.

Soil type	Sporobolus airoides	Sphaeralcea coccinea ecotypes			
		Gunnison	D.E.R.	Ouray	Alton
Blue Gate shale	81	97	94	np[1]	98
Penoyer topsoil	95	93	92	75	80
Persayo topsoil	85	←←←←←←←←←←←←←←90[2]→→→→→→→→→→→→→→			
Castle Valley topsoil	94	66	67	np	28
Blue shale subsoil	100	np	np	np	np

[1]np = ecotypes not planted on this soil.
[2]data not recorded by ecotype in 1980.

Supplement No. 2
to Study No. 6: Shrub Plantings on Blue Gate Shale

Objectives: (1) To compare growth and development of the same shrub species used in the main study on a new site where the topsoil is Blue Gate Shale.

Methods

An area approximately 60 x 100 feet in size was prepared for planting by stockpiling 15 inches of topsoil, ripping up the subsoil to a depth of 30 inches and replacing the topsoil. This work was done in the late fall of 1978, and the area was fenced to exclude livestock. This area is about 2 miles north of the 6-acre site.

Plantings of container-grown shrubs were made on this site on April 24, 1979. Insofar as possible the same species planted on the other 4 sites in the main study were used on this site. Plot size and spacings between plants were the same as on other sites. One liter of water was added to each plant at the time of transplanting. Similar amounts of water were added on 10 other occasions at 2 to 3 week intervals during the hot, dry summer of 1979 to keep plants alive. Sphaeralcea and Sporobolus were interspersed between shrub plants on this site as described in supplement No. 1.

Results

Some plants appeared more vigorous than others at the end of the 1979 growing season, but overall survival was generally high. Overall shrub growth did not seem so vigorous as on soils included on the other study sites at Emery.

The 1980 growing season was generally dry except for rains in early May and early September. No supplemental water was given plants in the second growing season (1980). Table 17 shows the mean percent survival of shrub species on September 18, 1980. As on most other sites where we have planted them, the two Russian species, prostrate summer cypress and Mediterranean camphorfume exhibited highest survival. Most other species showed survival percentages between 80 and 97 percent. However, the four hybrid saltbushes exhibited lower survival percentages, between 37 and 75 percent, and mean survival of Atriplex robusta was only 16 percent. Some of these plants were very small when planted.

The most vigorous species were Kochia prostrata, Camphorosma monospeliaca, Ceratoides papposa, Atriplex gardneri, and Atriplex canescens. Survival and development of these shrubs will be monitored each growing season over the next few years.

Table 17. Mean percent survival and mean height and diameter of shrubs on Blue Gate Shale at the end of the second growing season (1980)

Species symbol	Percent survival	Mean height (inches)	Mean Diameter (inches)
Atap	90.6	4.0	5.5
Atbo	81.2	5.0	5.2
Atca	93.8	7.2	9.2
Atca x Atcu	75.0	3.5	3.5
Atca x Atid	54.2	3.7	2.0
Atca x Attr	37.5	2.8	4.2
Atga	96.9	4.2	8.2
Atid	84.4	3.5	4.0
Atid x Attr	50.0	3.0	3.0
Atob	90.6	3.0	4.0
Atro	15.6	4.5	6.0
Attr	84.4	4.2	8.2
Camo	100.0	11.0	11.8
Cela	87.5	9.0	6.2
Cepa	93.8	8.8	7.8
Kopr 4	96.9	23.0	19.0
Kopr 7	100.0	14.8	13.5
Kopr 12	100.0	18.0	14.5
MEANS	79.6	7.4	7.5

Supplement No. 3
to Study No. 6: Adaptability of natural and developed Atriplex hybrids, and other Chenopod species

Objectives: (1) To determine survival and growth rate of natural and artificially developed Atriplex hybrids, and other Chenopod species on two soil types of the Emery coal field.

Methods

An area 42 x 96 feet in size was divided into 56 plots (14 in each of 4 replications), each 6 x 12 feet in size. The study area is located on the north side of, and adjacent to, the 1978 shrub planting on the 6-acre site. Depth of replaced Persayo topsoil decreases gradually from Block No. 1 through Block No. 4. Ten accessions of Atriplex and one accession of Ceratoides papposa were planted in a randomized block design. Eight container-grown plants of each accession were planted in 6- x 12-foot plots on April 26, 1979.

A second area, 24 x 156 feet in size was divided into 52 plots (13 in each of 4 replications), each 6 x 12 feet in size. The area is located north of, and adjacent to, the 1978 shrub planting on Castle Valley series topsoil. Ten accessions of Atriplex were planted on April 25, 1979, as described above. Each plant was watered with one liter of water immediately after being planted. Similar amounts of water were provided each plant on 10 other occasions at 2- to 3-week intervals during the 1979 growing season. No supplemental water was provided during 1980. Plot diagrams for these two separate plantings are included in the Appendix to this report.

Results

Table 18 shows survival on the Persayo and Castle Valley soils at the end of each of the first two growing seasons. Survival was excellent in 1979 on both soil types. At the end of the second growing season (1980) overall survival was higher on the Castle Valley soil than on the Persayo soil. Accessions that have suffered greatest mortality to date are Atriplex canescens from Yuma, Arizona, A. canescens from Sand Mt., Utah, and A. robusta. Among the most vigorous accessions were the hybrids A. bonnevillensis x A. tridentata, A. canescens x A. obovata, A. canescens x A. idahoensis, and Ceratoides papposa.

Table 19 shows the mean height and mean crown diameter of each accession on both soil types at the end of the second growing season (1980).

All of the seven accessions that were planted on both soil types exhibited larger size on the Castle Valley topsoil than on the Persayo topsoil. Ceratoide papposa made very good growth on the Persayo topsoil despite the dry summer of 1980. This introduced species from Russia seems well adapted to the climate and soils where it has been planted on the Emery coal field.

Data will be taken on these Chenopod accessions each year for the next few years in order to determine their adaptability over a period of time.

Table 18. Mean percent survival of shrubs on Persayo and Castle Valley soils after the first (1979) and second (1980) growing seasons.

Species symbol	Persayo topsoil		Castle Valley topsoil	
	1979	1980	1979	1980
Atbo x Attr	97.5	96.9	100.0	100.0
Atca (Yuma)	93.8	9.4	100.0	40.6
Atca (Sand Mt.)	93.8	50.0	93.8	43.8
Atca x Atco x Atca	87.5	53.1	90.0	84.4
Atca x Atid	100.0	93.8	np[1]	np
Atca x Atob	100.0	78.1	100.0	87.5
Atca x Attr	97.5	68.8	97.5	87.5
Atcu x Atco[2]	np	np	77.5	62.5
Atfa	75.0	0	90.0	87.5
Atid	np	np	100.0	100.0
Atla	100.0	84.4	100.0	100.0
Atro	87.5	62.5	np	np
Cepa	100.0	100.0	np	np
MEANS	93.9	63.3	94.9	79.4

[1]np = species not planted on this soil.

Table 19 . Mean height and crown diameter (inches) of shrubs on Persayo and Castle Valley topsoils at the end of two growing seasons.

Species symbol	Persayo topsoil		Castle Valley topsoil	
	Height	Crown diameter	Height	Crown diameter
Atbo x Attr	8.2	10.5	11.8	14.8
Atca (Yuma)	5.0	4.5	5.8	5.8
Atca (Sand Mt.)	10.2	4.5	11.2	5.5
Atca x Atco x Atca	4.5	4.5	7.8	9.0
Atca x Atid	9.2	12.8	np[1]	np
Atca x Atob	4.8	7.2	7.2	8.2
Atca x Attr	3.5	4.5	7.0	9.5
Atcu x Atco[2]	np	np	2.8	6.8
Atfa	0	0	9.0	12.0
Atid	np	np	11.8	14.5
Atla	5.0	5.2	8.5	10.2
Atro	3.5	3.5	np	np
Cepa	11.2	12.5	np	np
MEANS	6.5	7.0	8.3	9.6

[1]np = species not planted on this soil.

Study No. 7: Microclimatic Factors at the Emery Coal Field.

Objectives: (1) To characterize the air temperature regime at a height of 54 inches above the soil surface, (2) To characterize the soil temperature regimes at depths of 2 inches and 8 inches below the soil surface on two different soil types (Persayo and blue shale subsoil), (3) To determine the amount and pattern of precipitation received during the growing season at the study area, (4) To obtain information on soil water potential during the growing season on each of five different soil types on the study area.

Methods

On May 15, 1979, a battery-powered (solar charged) automatic data logger was installed at the 6-acre study area south of Emery. The data logger monitors six sensors at hourly intervals and stores the data on magnetic tape. Measurements taken are air temperature at 54 inches above the ground, soil temperature at depths of 2 and 8 inches on both Persayo soil and blue shale soil, and precipitation. In late May 1979, thermocouple psychrometers were installed in the soil of each of the five study sites south of Emery. Thermocouple psychrometry is one of the most recently developed methods for monitoring soil water potential. At each of the five sites, psychrometers were buried at depths of 8 and 20 inches, as follows:

1. On Persayo soil series; three locations on the cultipacked treatment, and three locations on the gouged treatment.

2. On Penoyer soil series; three locations on the cultipacked treatment, and three locations on the gouged treatment.

3. On Castle Valley soil series; two locations on the stockpiled topsoil area used to evaluate container-grown shrub species.

4. On blue shale subsoil, one profile material overlying local coal seams; two locations on the area used to evaluate container-grown shrub species.

5. On Bluegate Shale soil series; two locations, one ripped and one not ripped, on the area used to evaluate container-grown shrubs and forbs.

Results

Table 20 shows the monthly mean, mean maximum, and mean minimum air and soil temperatures from middle of May, 1979, through April 1980. Data for the growing season of 1980 has not yet been summarized from magnetic tapes (our data printouts are prepared by a Colorado firm, and these are often delayed).

Table 20. Mean, mean maximum, and mean minimum air and soil temperatures (C°), May 16, 1979 through April 30, 1980. Emery 6-acre study area.

		Soil temperature			
		Persayo series		Blue shale	
	Air @ 54"	-2"	-8"	-2"	-8"
Mean maximum					
May (16-31)	24.6	23.8	18.1	23.8	18.3
June	28.8	28.5	21.4	28.0	21.3
July	33.3	33.6	25.3	32.0	24.6
August	29.8	29.9	23.5	29.3	23.1
September	29.3	27.3	21.0	27.6	21.3
October	20.5	18.5	14.7	19.0	15.7
November	5.9	3.3	3.1	4.5	5.0
December	4.1	- 2.0	- 2.0	.1	.0
January	4.2	- .6	- .3	.1	.4
February	8.6	.9	.4	1.1	.8
March	7.8	5.0	3.7	5.5	3.9
April	16.3	11.3	8.6	13.8	9.4
Mean					
May (16-31)	16.4	17.2	16.2	18.1	16.8
June	19.8	20.8	19.3	21.5	19.8
July	24.1	25.4	23.6	25.3	23.4
August	21.0	22.2	21.8	22.7	22.0
September	19.7	19.5	19.5	20.6	20.2
October	11.7	12.0	13.5	13.4	14.8
November	- .8	- .3	2.3	1.0	4.2
December	- 2.6	- 4.5	- 2.7	- 3.0	- .5
January	- 2.2	- 1.5	- .6	- 1.3	.1
February	.7	- .7	- .1	- .6	.3
March	1.2	2.7	2.9	2.4	3.0
April	7.9	7.8	7.4	9.0	8.2
Mean Minimum					
May (16-31)	8.9	11.6	14.4	13.1	15.6
June	10.9	14.0	17.4	15.6	18.6
July	15.5	18.3	21.9	19.4	21.7
August	13.5	16.0	20.2	17.1	21.0
September	11.9	13.5	18.0	14.9	19.2
October	5.5	7.3	12.3	8.9	14.1
November	- 5.9	- 3.2	1.6	- 1.8	3.5
December	- 7.5	- 7.0	- 3.3	- 5.4	- 1.0
January	- 6.7	- 2.3	- .9	- 2.5	- .2
February	- 4.4	- 1.7	- .7	- 1.8	.0
March	- 4.0	1.1	2.3	.5	2.4
April	.3	4.8	6.4	4.9	7.2

The mean annual temperature for the period shown in Table was 9.7° C (49.5° F). This compares to a mean annual temperature of 9.4° C (48.9° F) at Ferron, which is presently the nearest NOAA weather station. Temperature of the lighter textured, and lighter colored, Persayo soil fluctuates more than the temperature of the heavier textured, and darker colored, blue shale subsoil. Persayo soil averaged approximately 0.75° C (1.35° F) cooler than the blue shale subsoil for the 12-month period.

Table 21 shows monthly extreme temperatures for the period May 16, 1979, through April 30, 1980.

The first soil water potential measurements in 1980 were taken on April 22. Subsequent measurements were made on four occasions during the growing season, with the last readings taken on October 6, 1980, (Table 22).

Soil moisture stress for plants on the study area probably began in late June, and continued until the heavy rains that came between September 7 and September 12. In contrast to 1979, the lighter-textured Penoyer soils exhibited lower soil water potentials in late June than did the Persayo soils. The reason may lie in the amount and timing of precipitation received during the two months prior to the June measurement.

Table 21 .--Monthly extreme temperatures (C°) recorded at the 6-acre study site. Emery coal field, Utah.

		Air at 54 in.	Persayo soil 2 in.	Persayo soil 8 in.	Blue shale soil 2 in.	Blue shale soil 8 in.
May (16-31) 1979	max.	29.3	28.1	19.9	28.3	19.8
	min.	2.6	7.7	12.7	8.6	13.5
June	max.	37.1	34.1	24.4	33.5	24.2
	min.	3.8	9.2	13.4	10.4	14.6
July	max.	37.2	37.0	27.0	35.5	25.9
	min.	9.3	14.7	19.4	16.1	20.2
August	max.	38.1	36.2	27.3	35.9	26.5
	min.	7.6	10.7	16.0	12.2	17.3
September	max.	33.8	31.0	22.9	33.0	23.1
	min.	6.4	9.6	15.7	11.2	17.3
October	max.	29.4	23.8	19.1	26.4	19.6
	min.	-7.3	-2.0	5.0	-0.3	7.5
November	max.	12.1	9.0	6.8	10.2	8.2
	min.	-13.9	-12.5	-5.7	-10.9	-2.4
December	max.	9.1	0.8	0.7	4.6	2.2
	min.	-15.5	-13.9	-6.2	-10.8	-2.9
January 1980	max.	11.9	4.8	2.0	5.3	2.2
	min.	-12.6	-8.1	-3.0	-6.9	-1.9
February	max.	15.4	6.0	3.5	9.0	4.4
	min.	-12.4	-6.5	-3.6	-6.6	-2.4
March	max.	13.1	7.8	4.8	10.2	5.2
	min.	-11.7	0.2	1.5	-0.9	1.5
April	max.	26.1	17.4	13.3	20.7	14.5
	min.	-10.7	0.0	1.2	-1.0	1.1

Table 22 . Soil water potential, as measured by thermocouple psychrometers, at Emery study sites, 1980.

	Soil depth	April 22	May 23	June 27	August 15	October 6
	(In.)			(bars)		
Persayo Series						
Cultipacked	8	-7	-5	-9	-30	-2
	20	-6	-6	-9	-51	-8
Gouged	8	-8	-7	-6	-22	-7
	20	-8	-7	-2	-37	-12
Penoyer Series						
Cultipacked	8	-10	-4	-36	-15	-5
	20	-8	-3	-23	-70	-7
Gouged	8	-7	-5	-10	-40	-5
	20	-6	-5	-2	-44	-5
Castle Valley Series						
	8	-9	-3	-18	-13	-10
	20	-4	-5	-17	-70	-74
Bluegate Shale						
Ripped	8	-10	-6	-9	-70	-6
	20	-13	-13	-12	-72	-35
Non-ripped	8	-3	-2	-14	-48	-3
	20	-6	-6	-5	-9	-7
Blue shale						
	8	-7	-6	-7	-16	-27
	20	-10	-12	-10	-12	-11

Study No. 8: Transplanting Native Trees at Emery

A new study was started at Emery in the spring of 1980 under Statement of Work Section 3.6. This was designated Emery Study No. 8.

Objectives: (1) To determine whether juniper and pinyon trees of different sizes can be transplanted successfully on disturbed sites in the Emery coal field, and (2) To evaluate growth of trees following transplanting.

Procedure

An end-loader bucket developed by the Missoula Equipment Development Center was used to move live trees. The bucket is designed to fit on a 988 end loader which is one of the larger types that can usually be found on mine sites. The bucket is 14 feet wide and 9-1/2 feet from front to back, which enabled moving a reasonable amount of roots with the trees. Both pinyon and juniper trees of various sizes in the vicinity of the 6-acre site were moved to the north side of the Mancos shale hill that was reshaped for planting of shrubs. Soils there are mainly of the Persayo series. A total of 12 pinyon and 19 juniper trees were transplanted on that site. Also, a total of 25 pinyon trees and 18 juniper trees were transplanted on the 4-acre study site where soils are of the Penoyer series.

Height and crown diameter of each tree was measured immediately following transplanting. Survival was determined in September 1980 and will be determined again in May 1981. Pinyon trees survived the first summer much better than did Utah juniper trees. Size made little difference in survival of pinyon trees, but small juniper trees survived much better than large juniper trees. Trees will be monitored for a period of at least 2 years to determine survival and growth rate of trees of different size classes.

Greenhouse Study
(Provo No. 6) | Germination and Emergence of Seeds from Three Emery Soils in the Greenhouse

Objectives: (1) To determine what plant species have viable seeds in topsoils of Emery, (2) to compare effects of a cold treatment on seed germination and establishment in the greenhouse.

Methods

Samples of 3 kinds of topsoils used in other studies were brought to the greenhouse for this study. Samples were obtained by making ten 1-square-foot scalps with a blunt-nosed shovel to a depth of 2 inches. Soil types included: Persayo soils near the 6-acre exclosure, Penoyer soils near the 4-acre exclosure and Castle Valley soils near the 2-acre exclosure. Soils were collected in the field November 22, 1978, and placed in containers December 5. Soil samples were spread 2-1/2 inches deep in containers 10 x 15 x 6 inches in size. Eight containers were used for each soil. Four containers of each soil were placed in a cold room at 3°C for a 4-week period. The other four containers were taken directly to the greenhouse.

As seedlings emerged, they were identified by toothpicks painted a specific color to represent a specific date of emergence. Counts and other observations were made every 2 to 3 days beginning December 19, 1978 and continuing to April 12, 1979. When containers from the cooler were removed to the greenhouse, a few seeds had already germinated. Rapid germination followed removal of these containers to the greenhouse.

Results

Data in Table 23 show that soil stratified in the cooler showed greater total germination than unstratified samples. Stratified seeds also germinated more quickly. Persayo soils showed most total germination and Castle Valley soils showed least germination. Earliest flowering occurred February 20 and flowering extended to mid-April. It was necessary to grow these plants for 4 months in the greenhouse in order to properly identify some species.

In addition to the 349 plants accounted for in Table 23, another 322 seedlings germinated and died without being identified.

Table 23. Numbers of plants germinating in greenhouse according to species, soil type, and stratification.

Species	Persayo		Penoyer		Castle Valley		Total	
	Strat.	NS	Strat.	NS	Strat.	NS	Strat.	NS
Lappula occidentalis	44	43	4	4	7	0	55	47
Lepidium densiflorum	0	0	0	3	5	0	5	3
Plantago purshii	0	1	0	4	6	0	6	5
Eriogonum cernuum	3	1	0	2	6	0	9	3
Gilia polycladon	18	9	0	0	0	0	18	9
Gilia pumila	2	2	2	0	0	1	4	3
Gilia leptomeria	3	0	0	0	1	0	4	0
Phacelia corrugata	0	0	3	0	0	0	3	0
Phacelia ivesiana	4	7	0	0	0	0	4	7
Machaeranthera tenacetifolia	0	0	0	2	4	0	4	2
Taraxacum spp.	0	0	0	1	4	0	4	1
Crypthantha spp.	4	2	0	4	2	0	6	6
Chenopodium incanum	2	0	0	0	1	0	3	0
Halogeton glomeratus	1	3	0	0	0	0	1	3
Sitanion hystrix	0	0	2	0	0	0	2	0
Sporobolus airoides	4	5	2	19	41	1	47	25
Oryzopsis hymenoides	6	0	0	0	0	0	6	0
Artemisia nova	1	0	12	0	0	3	13	3
Xanthocephalum sarothrae	1	2	17	0	0	3	18	5
Ceratoides lanata	1	0	0	0	0	0	1	0
Unknown (resinous whorls)	1	0	4	0	0	7	5	7
Unknown grass	1	0	0	0	0	0	1	0
Unknown broadleaf	1	0	0	0	0	0	1	0
TOTAL	97	75	46	39	77	15	220	129

Mycorrhizal Study (Provo No. 7) Role of Mycorrhizal Fungi in Mineral Uptake and Nutrition of Plants Used in Revegetation of Mine Spoils

This study is being conducted at several sites where vegetation studies are underway. A short summary was also presented in the Alton report.

Objectives: (1) To assess the association of mycorrhizal fungi with host plants.

Methods

The association of a mycorrhizal fungus with a host plant root is known to increase plant growth and aid in uptake of nutrients, especially phosphorus. Recent studies by several investigators indicate that most of the climax plant species in western rangelands are vesicular-arbuscular (VA) mycorrhizal. Establishment of VA mycorrhizal relationships will likely prove important in rehabilitation of reconstructed soils on western mined lands.

A preliminary survey of plants growing on reconstructed soils and also on undisturbed sites at our research locations revealed a high frequency of mycorrhizal colonization. A spore population study is currently underway in order to determine the species of VA fungi present at each site and the relative numbers of each. Soil samples were collected from the root region of the major species growing on three different soil types. Spore identification has so far revealed Glomus fasciculatus as a common member of the spore population.

Sampling of undisturbed communities at the Emery study site identified the following species as mycorrhizal:

Atriplex confertifolia
Atriplex cuneata
Hilaria jamesii
Oryzopsis hymenoides
Chrysothamnus nauseosus
Xanthocephalum sarothrae
Chrysothamnus viscidiflorus var. stenophyllus
Eriogonum jamesii var. flavescens
Sphaeralcea coccinea
Machaeranthera grindelioides var. grindelioides
Leptodactylon pungens
Bouteloua gracilis
Sporobolus airoides
Bahia oblongifolia
Opuntia sp.

Seedings of Indian ricegrass and crested wheatgrass were also mycorrhizal. Planted shrubs of fourwing saltbush and winterfat were non-mycorrhizal.

SUMMARY AND CONCLUSIONS

Studies No. 1 and 3 are being conducted on Persayo soils at the 6-acre site. Studies No. 2 and 4 are being conducted on Penoyer soils at the 4-acre site. Study No. 5 is being conducted on Castle Valley soils at the 2-acre site. Study No. 6 is being conducted on all of the above soils plus bluegate shale. Study No. 7 is concerned with microclimate. Study No. 8 was added in 1980 and is being conducted on both Persayo and Penoyer soils. A greenhouse study and new mycorrhizal study are designated as "Provo" studies.

Because of the aridity of the Emery Coal Field supplementing water will be required in certain years for plants to establish from seeds. This is especially true of warm-season grasses such as alkali sacaton and blue grama. Fall planting is recommended, but seeds of so-called warm-season grasses did not germinate so readily in the spring as seeds from cool-season grasses. Container-grown plants of 4 warm season grasses were added to studies 1 and 2 in 1980. Tyis method of plant establishment can insure successful revegetation of these arid soils, but their use will be more costly than use of seeds.

Introduced grasses of the crested wheatgrass complex have become established more readily and produced higher early yields than native species. A mixture of both native and introduced species should be used for revegetating arid soils of the Emery Coal Field to provide quick early cover and sustained production over time.

A distinct advantage of the alfalfa hay amendment applied prior to seeding in 1977 showed up in the third growing season (1980). Alfalfa and grass hay mulches were superior to a bark-wood fiber compost.

From the standpoint of grass frequency, harrowing the soil surface proved superior to gouging (pitting) and/or cultipacking the soil surface. It is expected that the full advantage of gouging has not yet been demonstrated but will become more pronounced as drought periods occur.

A variety of shrub species can be used successfully on the various soils of the Emery Coal Field. The superiority of topsoil over subsoil is quite apparent. Loams and sandy loams appear superior to a clay loam topsoil.

OUTLOOK

These studies will be monitored over at least 2 more years to determine changes with time and which species and treatments prove to be superior.

APPENDIX

LIST OF PLANT SPECIES CITED IN THIS REPORT

GRASSES

Symbol	Scientific name	Common name
AGCR	Agropyron cristatum	Fairway wheatgrass
AGCR(H)	A. cristatum (hybrid)	Induced tetraploid wheatgrass
AGDE	A. desertorum	Nordan crested wheatgrass
AGIN	A. inerme	Bearded bluebunch wheatgrass
AGRI	A. riparium	Streambank wheatgrass
BOCY	Bouteloua gracilis	Blue grama
ELJU	E. junceus	Russian wildrye
ORHY	Oryzopsis hymenoides	Indian ricegrass
SIHY	Sitanion hystrix	Bottlebrush squirreltail
SPAI	Sporobolus airoides	Alkali sacaton
SPCR	S. cryptandrus	Sand dropseed

FORBS

CRSP	Crypthantha spp.	--
CHIN	Chenopodium incanum	--
ERCE	Eriogonum cernuum	Nodding eriogonum
GILE[2]	Gilia leptomeria	--
GIPO[2]	G. polycladon	--
GIPU	G. pumila	Dwarf gilia
HAGO	Halogeton glomeratus	Halogeton
LAOC	Lappula occidentalis	Annual stickseed
LEDE	Lepidium densiflorum	Prarie pepperweed
MATE	Machaeranthera tenacetifolia	Tansyleaf aster
PEPA	Penstemon palmeri	Palmer penstemon
PHCO	Phacelia corrugata	--
PHIV	P. ivesiana	--
PLPU	Plantago purshii	Wooly plantain
TASP	Taraxacum spp.	Dandelion

SHRUBS

Symbol	Scientific name	Common name
ARNO	Artemisia nova	Black sagebrush
ATAP	Atriplex aptera	Shortwing saltbush
ATBO	A. bonnevillensis	Bonneville saltbush
ATCA	A. canescens	Fourwing saltbush
ATCA X ATCU	A. canescens X A. cuneata	Fourwing hybrid saltbush
ATCA X ATID	A. canescens X A. idahoensis	Fourwing hybrid saltbush
ATCA X ATTR	A. canescens X A. tridentata	Fourwing hybrid saltbush
ATCO	A. confertifolia	Shadscale
ATGA	A. gardneri	Gardner saltbush
ATNA	A. navajoensis	Navajo saltbush
ATOB	A. obovata	Broadscale saltbush
ATRO	A. robusta	--
ATTO	A. tooelensis	--
ATTR	A. tridentata	--
CELA	Ceratoides lanata	Whitesage
CEPA	C. papposa	Plumed whitesage
EPNE	Ephedra nevadensis	Nevada ephedra
ERCO[7]	Eriogonum corymbosum	Combed eriogonum
GRSP	Grayia spinosa	Spiny hopsage
KOPR	Kochia prostrata #7, #11, #14 (clay sources)	Prostrate summer cypress
KOPR	K. prostrata #2, #9, #12 (sandy sources)	Prostrate summer cypress
KOPRV	K. prostrata var. villosissima	Hairy prostrate summer cypress
CAMO	Camphorosma monspeliaca	Mediterranean camphorfume
XASA	Xanthocephalum sarothrae	Snakeweed

1980 ADDITIONS

ATCO[2]	Atriplex corrugata	Matscale saltbush
ATCU	A. cuneata	Moundscale saltbush
ATFA	A. falcata	Falcate saltbush
ATID	A. idahoensis	
ATLA	A. lahontanensis	Lahontan saltbush
CAMO	Camphorosma monspeliaca	Mediterranean camphorfume

6- acre site - new area

Planted 4/26/79

Atca x Atco x Atca	Atca (gigas) Sand Mtn	Atca x Attr		Atca x Atid	Atca (yuma)	Atca x Atob	BLOCK 1
	Atla	Cepa		Atbo x Attr	Atro		
Atca (gigas) sand mtn		Atca (yuma)	Cepa	Atca x Atob	Atca x Atid	Atca x Attr	BLOCK 2
	Atro		Atla		Atbo x Attr	Atca x Atco x Atca	
Cepa		Atla	Atro	Atca x Atco x Atca	Atca x Atid		BLOCK 3
Atca (yuma)		Atbox Attr	Atca x Attr	Atca (gigas) sand Mtn	Atfa ②	Atca x Atob	
Atca x Atid		Atla	Atro	Atca (yuma)	Atca (gigas) Sand Mtn	Atfa	BLOCK 4
Atca x Attr	Atca x Atob			Cepa	Atbo x Attr	Atca x Atco x Atca	

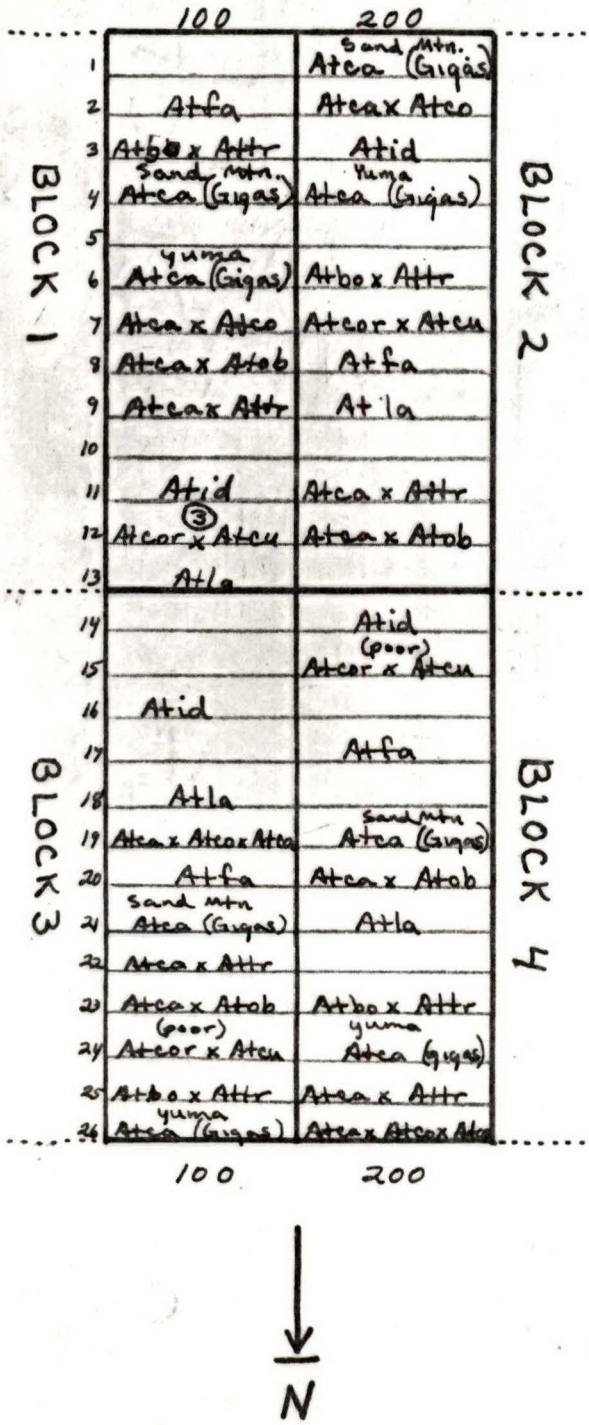
The same species were used as were used on the new Hilltop area. All plants were from H. Stutz except for Cepa which we grew.

21 plants of Cepa were planted 5/16/79 to complete BLOCKS 1, 2, & 3.

Lack At. falcata in BLOCKS 1 and 2 plus 6 plants in BLOCK 3 (Total = 22 plants needed)

New Hilltop Shrub Plots

Planted 4/25/79



1. Atriplex canescens (gigas) yuma
2. Atriplex canescens (gigas) sand Mtn, ♦
3. Atriplex falcata
4. Atriplex lahontanensis
* 5. Atriplex idahoensis (ours)
6. Atcor x Atcu
7. Atbo x Attr
8. Atca x Atob
9. Atca x Attr
10. Atca x Atco x Atca

* Grown in Forest Service greenhouse
All others from H. Stutz

The plots were 6' x 12' with 8 plants per plot spaced 36" apart. 1 liter of water given each plant as planted.

Lacked 5 plants of Atcor x Atcu in BLOCK 1